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To Mr. F.J. Kee
Director of Research

ANALYSIS OF THE EFFECT OF THERMAL UPGRADING ON HOUSEHOLD HEATING REQUIREMENTS

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The reducing effect of thermal upgrading on the heat loss from houses was studied. Field data from various houses (before and after thermal upgrading) were analyzed and the results showed that thermal upgrading generally reduces the heat loss. The amount of loss depended on the type of energy conservation method used.

INTRODUCTION

Thermal upgrading of residential houses has been popular in recent times as a means of conserving energy and reducing household heating costs. Thermal upgrading involves retrofitting houses with storm windows, window sealing and additional wall, attic or basement insulation. These measures are designed to reduce heat loss and capitalize on free heat gains. Free heat is defined as heat supplied by sources other than the furnace. Some examples of free heat are solar gain and internal heat gains from appliances and occupants.

Initiated by the Utilization Section of the Electrical Research Department, a study of the effect of thermal upgrading on the heating system load (HSL) is described in this report. For any given house, the HSL is a function relating outdoor temperature to household heating load. In this study, a straight line is used to model the HSL. The slope of this straight line is the rate of change of heating load to outdoor temperature. The effectiveness of thermal upgrading in reducing heat loss and retaining free heat gain is assessed by comparing the slopes of the HSL of a house before and after thermal upgrading. Thermal upgrading is expected to decrease the slope since more heat is retained in the house and this implies a smaller change in heating load in response to a given change in outdoor temperature.

job	file	date	report no.
740672-701	809.7	January 11, 1985	84-406-K

DATA USED FOR THE ANALYSES

Sixteen houses, each equipped with a dual oil-electric heating system (oil furnace/plenum heater) are included in this study. The houses are located in and around Belleville, North Bay, Ottawa and Toronto. The type of thermal upgrading installed differs from house to house. For instance, one house may have added wall insulation while another may have this in addition to sealed windows. For the precise modifications made in each house refer to /1/.

For each house, hourly electric heating data and the corresponding outdoor temperature were collected for the 1981-82 heating season (before thermal upgrading) and for the 1982-83 heating season (after thermal upgrading). The heating season runs from September of one year to May of the following year.

ESTIMATING THE HEATING SYSTEM LOAD

The outdoor temperature is divided into small temperature intervals. Within each interval, the average electric load is calculated. In this way, the average electric load curve, which relates the average electric load to the outdoor temperature, is produced for each house. This data is then plotted and the general shape of this scatter diagram is shown, for a given house, in Figure 1.

The diagram can be divided into three parts:

1. a section where the electric heating load decreases as the outdoor temperature decreases;

2. a relatively linear section where the electric heating load increases as the outdoor temperature decreases; and

3. a section at higher outdoor temperatures where the electric heating loads are very small and relatively independent of the outdoor temperature.

The first section is the result of switching from the plenum heater to the oil furnace for heating during colder temperatures. A two-stage thermostat control is used and it operates by turning on the plenum heater first in response to a drop in the indoor temperature. When the temperature drops further, the plenum heater is turned off and the oil heater is switched on, and the two will alternate, with the proportion of time when the oil heat is on increasing as the outdoor temperature decreases. The second section corresponds solely to electric space-heating. The third section is due to the persistent, but limited, use of the plenum heater during warmer temperatures. Judgement was used by researchers of the Utilization Section to determine the transition between the sections. These transitions were held constant for each house before and after thermal upgrading.

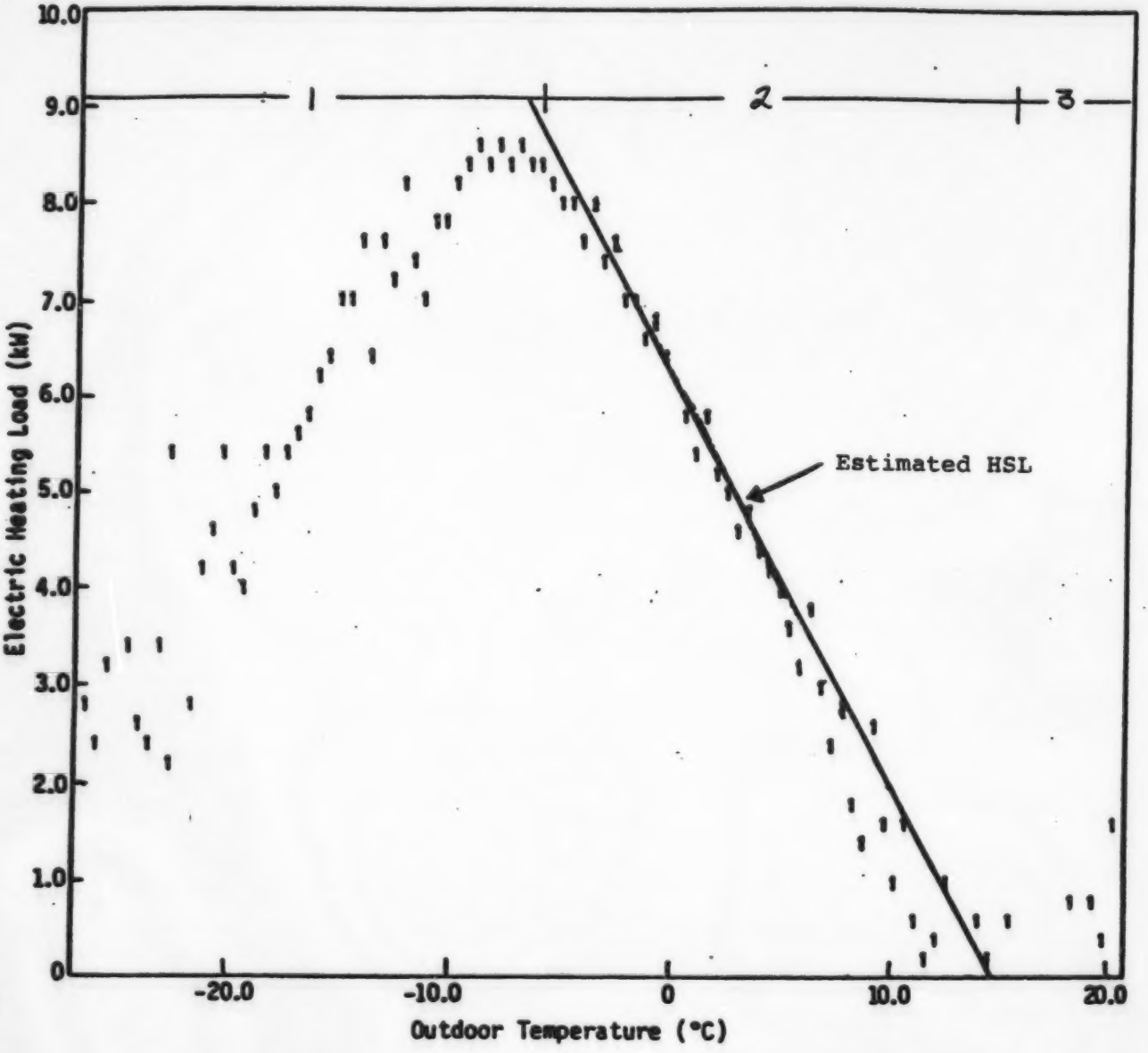

FIGURE 1

AVERAGES USED FOR ESTIMATING THE HSL FOR A GIVEN HOUSE

After exploring many ways of estimating the heating system load, the most appropriate method was judged to be to fit a straight line to the linear portion of the average electric load curve (Figure 1, Section 2). The fitting is done by weighted least squares regression using the number of observations at each temperature as weights.

COMPARISON OF RESULTS FROM THE TWO YEARS

The slopes of the HSL from before thermal upgrading (1981-82) and after thermal upgrading (1982-83) are compared in Table 1. The 'difference' is the difference in slope of the straight lines representing the HSL's for the two heating seasons, and the 'percentage decrease' refers to the difference expressed as a percentage of the 1981-82 slope. The 95% lower and upper confidence bounds for the differences are also shown. The interpretation of these bounds is that, with 95% probability, the difference will be between them.

For most houses, the slope decreased after thermal upgrading. This was as expected. The percentage decrease depends on the type of retrofit used on the house and how successful it is in reducing heat loss.

However, there are three exceptions to this trend (houses 6, 10 and 22). Investigation of the data indicated problems with the data for houses 10 and 22. As for house 6, the upper and lower bounds indicate that the difference estimated can also be negative. This implies that there is very little difference before and after thermal upgrading.

CONCLUSION

Thermal upgrading of a house generally decreases the slope of the HSL, ie, it reduces the heat loss. The amount of decrease depends on the type and effectiveness of the retrofit measure. How the HSL is affected by the various types of thermal upgrading will be examined by the Utilization Section in a subsequent study.

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TABLE 1

SLOPE COMPARISONS BETWEEN 1981-82 AND 1982-83

House	Slope 82-83 (kW/c)	Slope 81-82 (kW/c)	Difference (kW/c)	Decrease %	Lower Confidence Limit (kW/c)	Upper Confidence Limit (kW/c)
4	-0.289	-0.411	0.122	30	0.116	0.129
6	-0.173	-0.176	0.003	1	-0.001	0.006
7	-0.134	-0.161	0.027	17	0.025	0.028
9	-0.331	-0.416	0.085	21	0.082	0.089
10	-0.242	-0.227	-0.015	- 6	-0.017	-0.013
12	-0.187	-0.207	0.021	10	0.015	0.027
14	-0.258	-0.319	0.060	19	0.058	0.063
15	-0.151	-0.196	0.045	23	0.040	0.050
22	-0.197	-0.188	-0.008	- 4	-0.013	-0.004
25	-0.216	-0.264	0.048	18	0.045	0.050
26	-0.175	-0.188	0.013	7	0.012	0.015
27	-0.172	-0.209	0.038	18	0.035	0.041
28	-0.166	-0.208	0.042	20	0.039	0.045
32	-0.116	-0.130	0.013	10	0.013	0.014
33	-0.151	-0.165	0.014	8	0.013	0.015
34	-0.123	-0.156	0.032	21	0.032	0.033

REFERENCE

1. Jones, W.R., "The Effect of Thermal Envelope Upgrading in Residential Dwellings," Research Division Report, to be issued.

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